Optimizing for Social Impact: Enhancing Efficiency and Equity

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Optimization for Societal Impact

- **Societal Impact** can be defined as "the **effect of research in the real world** – a change or benefit beyond academia to the economy, society, culture, *public policy or services, health, and the environment or quality of life*"*.

- **Analytics and Optimization** should be part of the general response of the governments and the society to these problems, helping **making better decisions** and leading to a high positive impact on the society.

* https://www.purdue.edu/engagement/research-impacts/

Outline

1. Optimizing an integrated home care services problem
2. Improving the accessibility to public schools in urban areas of developing countries
3. Social Care Organizations
   - Optimization in Assistive Technology programs
4. Heuristic Algorithm Tool for Planning Mass Vaccine Campaigns
5. Mobility Optimization for Social Care Services
6. Actual Work, Lessons Learned and Conclusions

1. Optimizing an integrated home care services problem

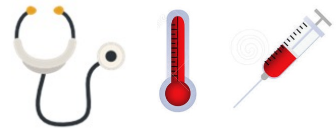
- de Aguiar, A.R., Gomes, M.I., Ramos, T., **Ramalhinho, H.** (2024). A Hybrid Biased-Randomized Heuristic for a Home Care Problem with Team Scheme Selection. In: Sevaux, M., Olteanu, AL., Pardo, E.G., Sifaleras, A., Makboul, S. (eds) Metaheuristics. MIC 2024. *Lecture Notes in Computer Science*, vol 14753 . Springer, Cham. https://doi.org/10.1007/978-3-031-62912-9_19
- De Armas J. Fabri M. and **Ramalhinho H.** (2024) Impact of Quality of Service in the Direct Cost of Integrated Home Care Services, *Health Systems*. https://doi.org/10.1080/20476965.2024.2313465
- Vieira B., De Armas J., **Ramalhinho H.** (2022), Optimizing an integrated home care problem: a heuristic-based decision-support system, *Engineering Applications of Artificial Intelligence*, volume 114. https://doi.org/10.1016/j.engappai.2022.105062

Home Care Services

- **Home Care** could be understood as health and social care provided to a person in the place, he/she lives with the aim to maintain him/her at his own environment and achieve a maximum level of **health, quality of life and wellbeing and autonomy**.
- **Integrated Home Care** is a model of care where different professionals from health and social care **act jointly**, sharing information and goals and taking joint or **coordinated decisions** to guarantee Integrated Care at home.

Home Care Services

- **Home Health Care (HHC)** is defined as "medical and paramedical services delivered to patients at home".
  - The basic forms of Home Health Care are Home Hospitalization and In-Home Primary Health Care.



- **Home Social Care (HSC)** refers to provide social work, personal care, protection or social support services to risk or needed population due illness, disability, old age or poverty.
  - The HSC services include a great variety of services as cleaning activities; companionship activities, personal care, delivery meals at home, etc.

Actual situation

Home Health and Social Care

- ► **The impact of Synchronization in Home Health and Social Care Services**
  - * Jésica de Armas, Marcelus Fabri, Helena Ramalhinho (UPF)
- ► **Optimizing an integrated home care problem: a heuristic-based decision-support system**
  - * Bruno Vieira, Jesica de Armas, Helena Ramalhinho

- The aim is to design and develop new mathematical models and optimization algorithms for the routing and scheduling problems associated to the syncronization of both HHC and HSC, obtaining integrated HHSC:
- **Scheduling**: assignment of staff members to jobs along the planning horizon
- **Routing**: creation of the corresponding routes for the staff members

Home Health and Social Care

- Mixed Integer Programming Model
  - Main decision variables

- $\beta_{in} \in \{0,1\}$: 1 if the caregiver $n \in \mathcal{N}$ need a break before the job $i \in \mathcal{J}$
- $p_{nt} \in \{0,1\}$: 1 if the caregiver $n \in \mathcal{N}$ need a break on day $t \in \mathcal{T}$
- $w_i \in \mathbb{R}$: Waiting time before job $i \in \mathcal{J}$
- $x_{ijn} \in \{0,1\}$: 1 if job j is performed by caregiver n directly after job i, $(i,j,n) \in \Omega_i^+$
- $z_i \in \mathbb{R}$: Start time of job $i \in \mathcal{J}$

- $s_i \in \mathbb{R}$: Tardiness of job $i \in \mathcal{J}$
- $e_i \in \mathbb{R}$: Earliness of job $i \in \mathcal{J}$
- $\delta_{nk} \in \{0,1\}$: 1 if the caregiver $n \in \mathcal{N}$ is associated to caretaker $k \in \mathcal{K}$
- $n_k \in \mathbb{N}$: Number of caregivers working for each caretaker $k \in \mathcal{K}$

Home Health and Social Care

- Objective function
  - Minimize total time
    - * travel times, waiting times, and breaks

$$\text{minimize} \quad \sum_{i\in\mathcal{J}}\sum_{j\in\mathcal{J}}\sum_{n\in\mathcal{N}} d_{ij}x_{ijn} + \sum_{i\in\mathcal{J}} w_i + \sum_{n\in\mathcal{N}}\sum_{t\in\mathcal{T}} B\cdot p_{nt}$$

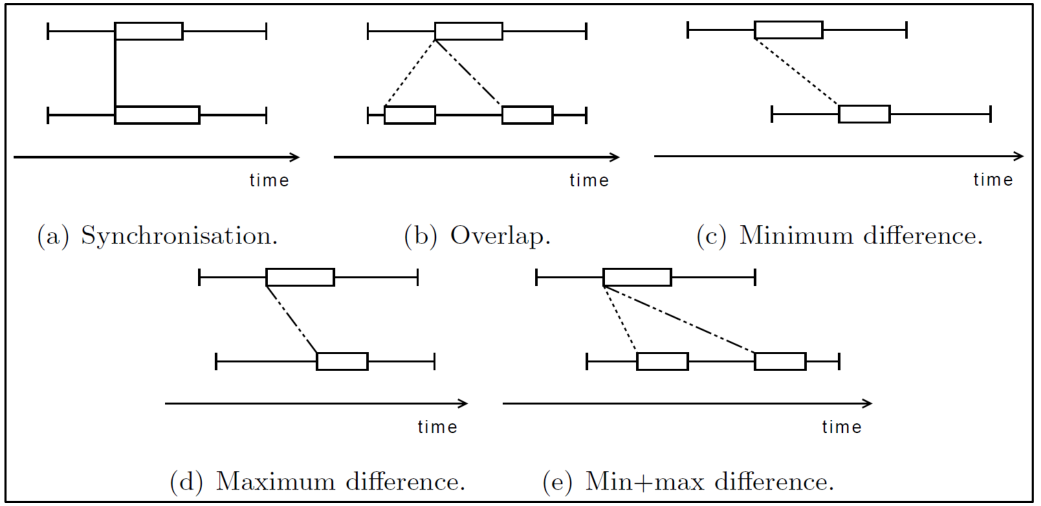
  - Maximize service quality
    - * Caregivers loyalty and soft time windows

$$\text{minimize} \ \frac{\sum_{k\in\mathcal{K}^0}\sum_{n\in\mathcal{N}} y_{nk}}{\sum_{k\in\mathcal{K}^0} C_k} + \frac{\sum_{K\in\mathcal{K}} n_k}{\sum_{K\in\mathcal{K}} J_k}$$

$$\text{minimize} \ \frac{\sum_{i\in\mathcal{J}} e_i + s_i}{\sum_{i\in\mathcal{J}} h_i} + \frac{\sum_{(i,j)\in\mathcal{J}^{syn}} \mu^+_{(i,j)} + \lambda^-_{(i,j)}}{\sum_{(i,j)\in\mathcal{J}^{syn}} g_{ij}}$$

Home Health and Social Care

- Constraints
  - General Constraints
    - * Each job must be done
    - * Caregivers schedule
  - Working Regulations
  - Breaks
  - Interdependencies
  - Continuity of care

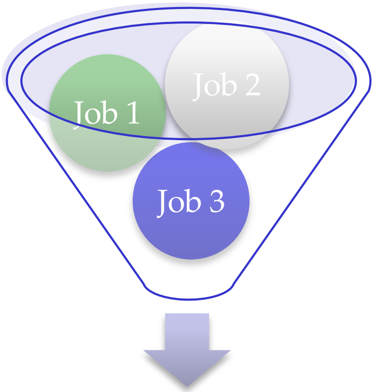


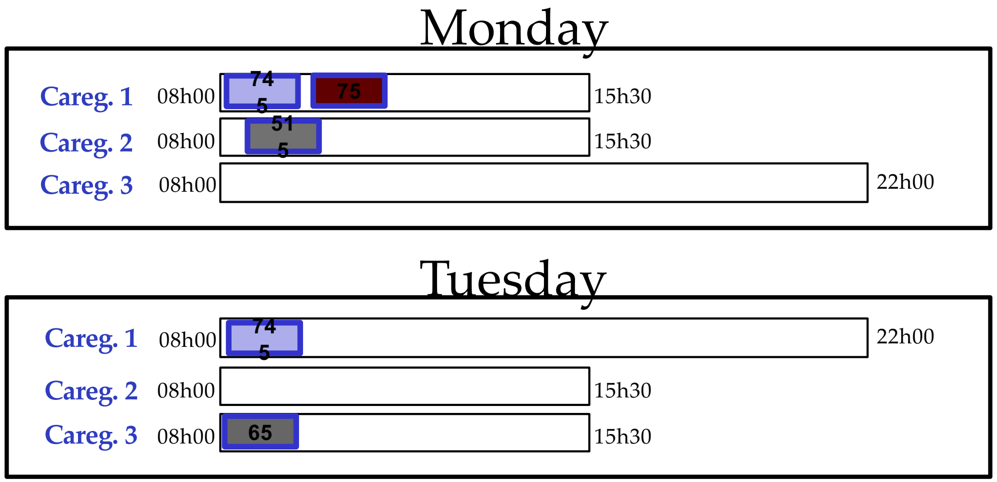
(a) Synchronisation. (b) Overlap. (c) Minimum difference. (d) Maximum difference. (e) Min+max difference.

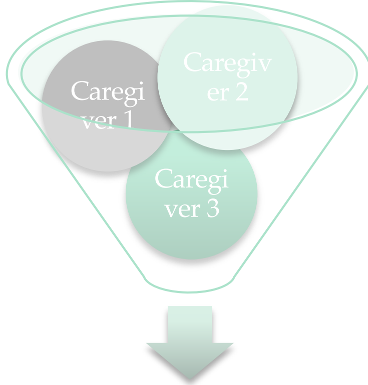
- Small instances are solved with CPLEX and larges one are solved by a heuristic approach.
  - Optimizing an integrated home care problem: a heuristic-based decision-support system (Bruno Vieira, Jesica de Armas, Helena Ramalhinho)

Method “ConstructByCaregiver” (CxC)

Primary objective: minimize non-effective working time **(travel + waiting time)**







1) Select caregiver with the **lowest workload** assigned so far

caretaker

	745	515	5	65	75
monday	745	515			75
tuesday	745			65	75
wednesday	745	515	5		75
thursday	745			65	75
friday	745	515			75

2) Select ***feasible*** job with the **lowest**:

a) travel + waiting time (p)

b) travel + waiting time + duration (1-p)

Does it imply a change in the habitual caregiver ?

Add **penalty** **(e.g. 25 min)**

Tuesday, caregiver 3:

Caretaker 65 = 10 + 10 = 20

Caretaker 745 = 5 + 10 = 15 + 25 = 40

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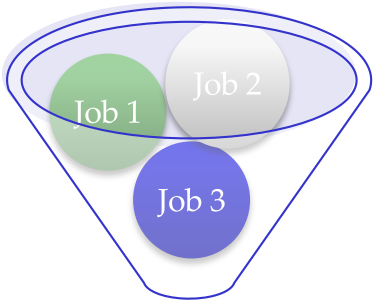
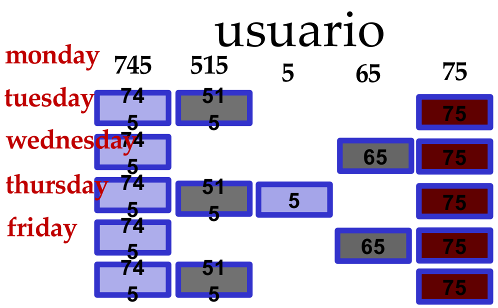
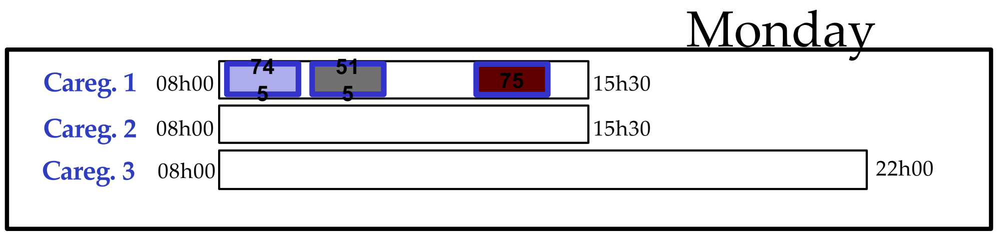
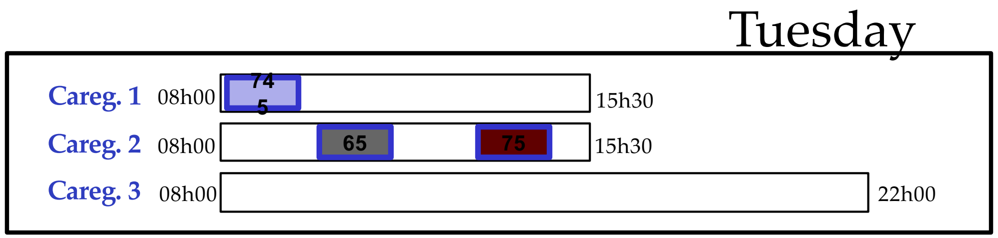
Method “ConstructByPatient” (CxP)

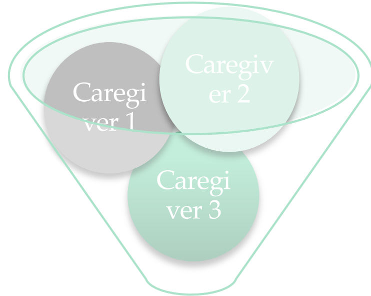
Primary objective: **minimize changes in caregiver-caretaker assignments (continuity)**











1) Select caretaker with (the highest number of) ***feasible*** jobs with the **lowest**:

a) travel + waiting time (p)

b) travel + waiting time + duration (1-p)

2) Select **caregiver already (pre-)assigned to this caretaker**. If none, select the one with the **least workload**

Travel + waiting time > **limit ?** (e.g. 90 min)

Select another caregiver for all jobs of this caretaker.

If not posible, split jobs amongst caregivers.

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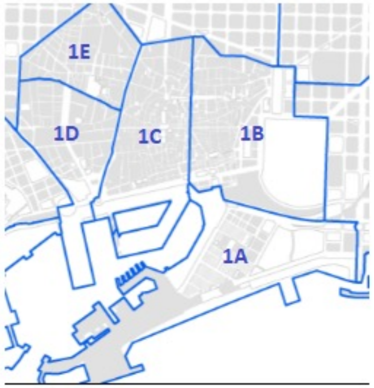
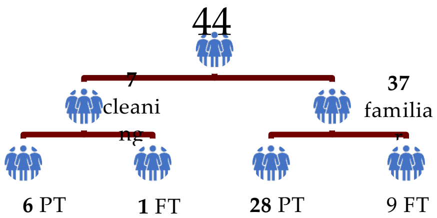
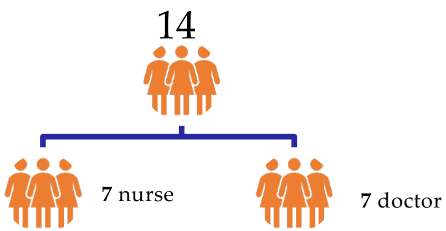
Data-set

Centro Servéis Social (CSS)



Areas de Salud





Data	Social	Health
Planning week:	**02/03/2020 – 08/03/2020 (historical)**	**Randomly generated**
Zone:	**1A (La Barceloneta)**	**1A (La Barceloneta)**
Jobs:	790 (13%/87%)	213 (77%/23%)
Caretakers:	227	179
Caregivers	44	14
Iteration limit:	1000	
Prob. crit1 / crit 2:	50%	
Penalization per unscheduled job:	1000	

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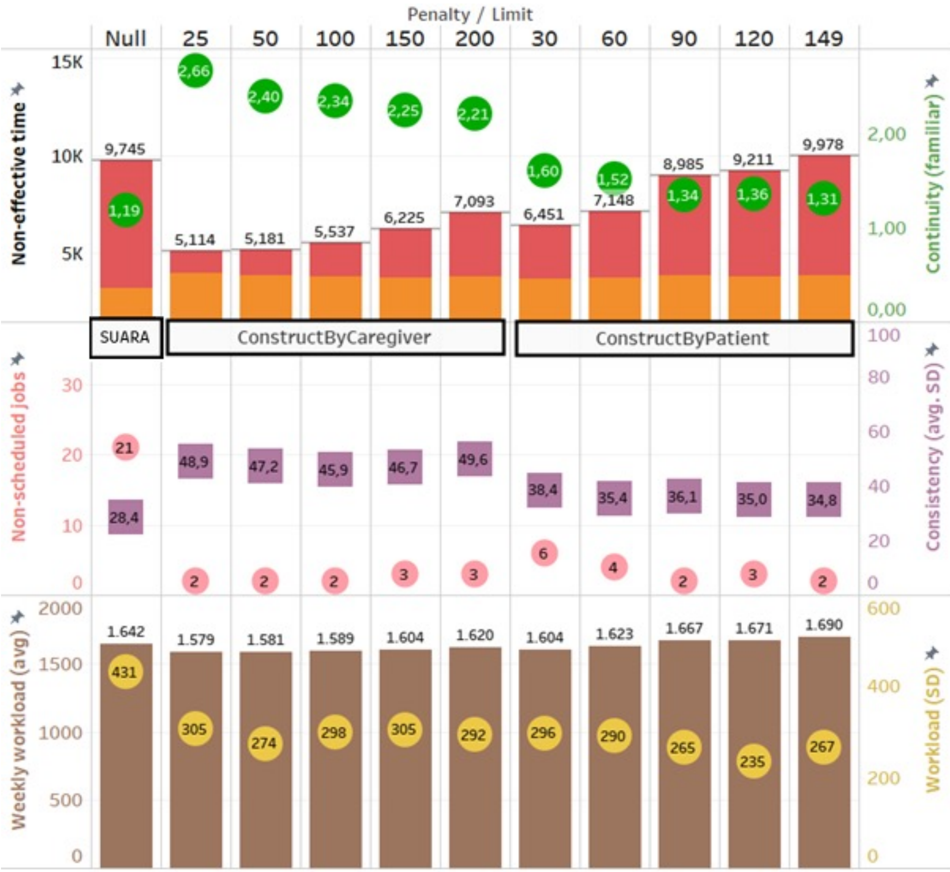
Results – Social services



Non-effective time = Travel + Waiting times

Continuity = avg. number of caregivers per caretaker

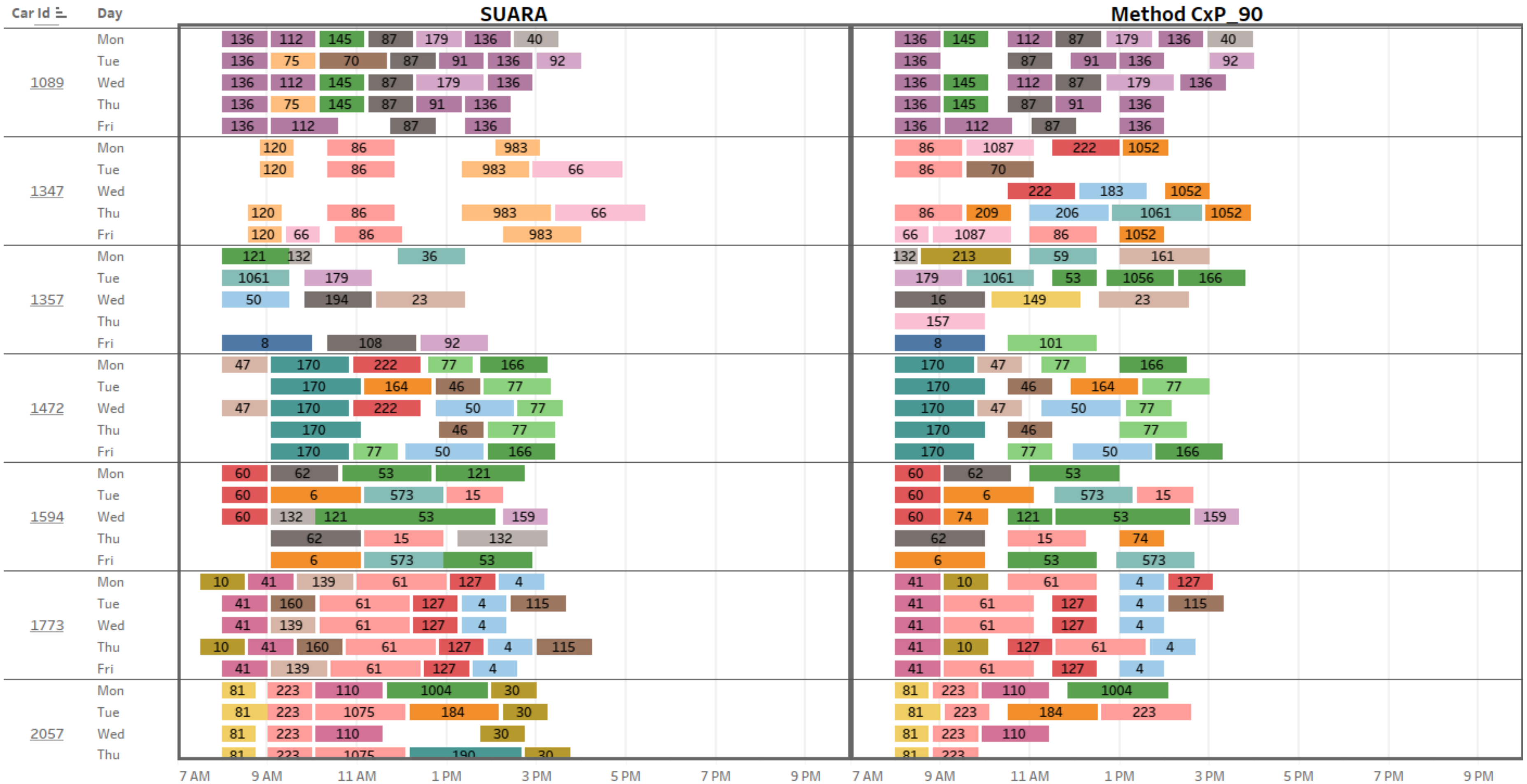
Non-scheduled jobs = number of jobs to be (manually) scheduled "a posteriori"

Consistency = average standard deviation amongst "same-type" jobs per caretaker

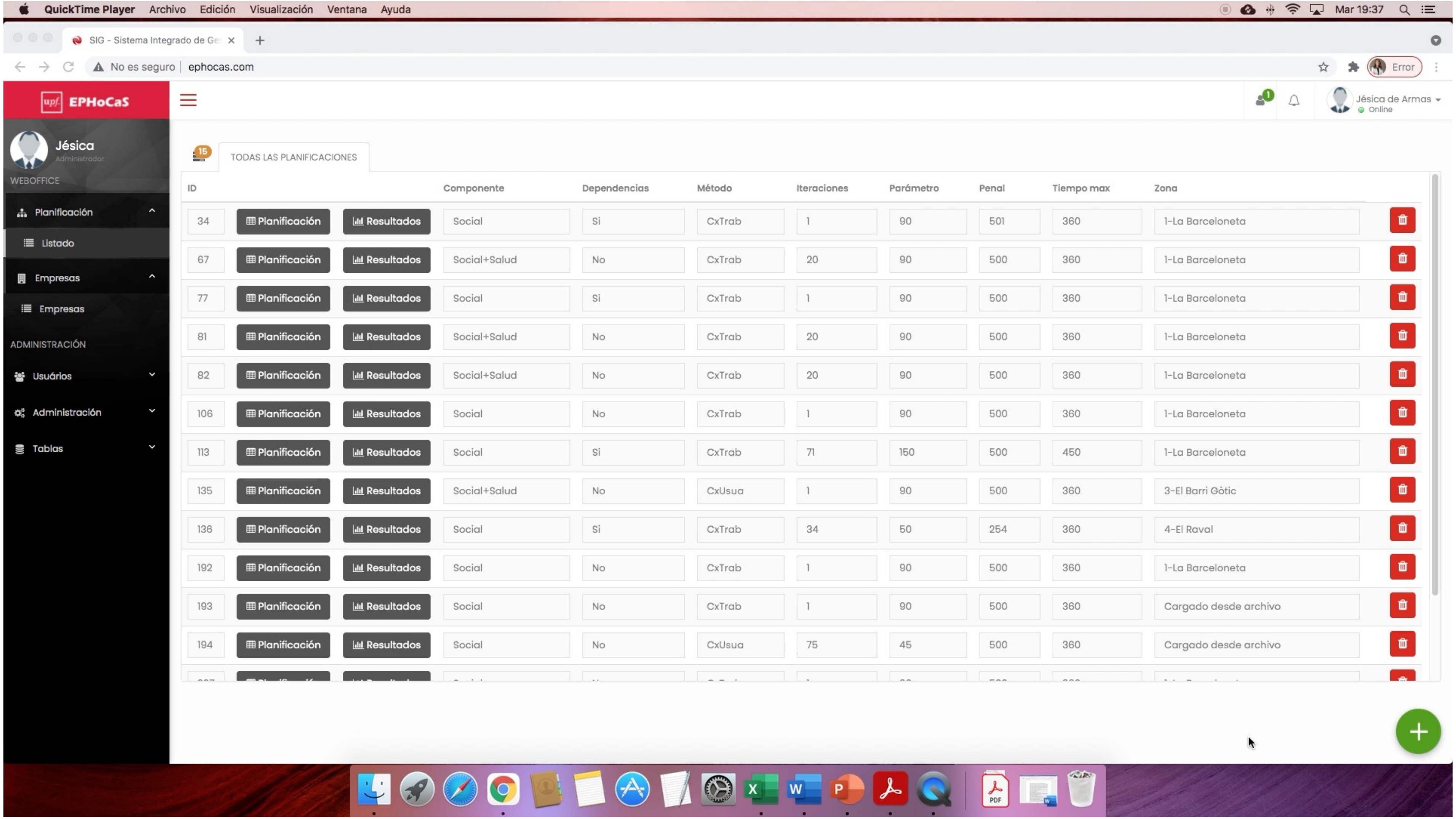
Workload = average weekly workload per caregiver

Workload (SD) = standard deviation workload

Solution – Social services



Web-based system to optimize home care



2. Improving the accessibility to public schools in urban areas

- De Armas J., Ramalhinho H. and Reynal-Querol M. (2022), Improving the accessibility to public schools in urban areas of developing countries through a location model and an analytical framework, PLOS ONE https://doi.org/10.1371/journal.pone.0262520

Access to Education - motivation

- The impact of the educational system on the growth and development of a country is well known.
  - Access to education, particularly at initial stages of education, leads to added value and employment growth, an increase in the GDP, and reduction of social and economic inequalities.
- The focus of the this work is on the location of public schools in relatively poor areas that are likely to see substantial population increases in coming years.
  - An example of this kind of area is Ciudad Benito Juárez, a city located in the eastern part of the Monterrey metropolitan area in the state of Nuevo León, Mexico

Problem characteristics

- Variation of p-median problem
  - Current schools are taking into account
  - Resizing schools
  - Capacity of the schools

Table 1. Comparison of approaches.

Paper	Location Problem	Objective	f1	f2	f3	f4	f5	f6	f7
[25]	Maximal coverage	Coverage maximization	✗	✗	✗	✗	✓	✓	✗
[26]	Capacitated maximal coverage	QoS maximization	✓	✗	✗	✗	✓	✓	✗
[27]	P-median	Distance minimization	✗	✗	✗	✗	✗	✓	✗
[33]	Dynamic Modular Capacitated Facility Location	Total discounted (socioeconomic) cost minimization	✓	✓	✓	✓	✗	✗	✓
[29]	P-median	Distance minimization	✓	✗	✗	✗	✗	✗	✗
[30]	Hierarchical p-median	Travel cost minimization	✓	✗	✗	✓	✗	✓	✗
[28]	P-median	Distance minimization	✗	✗	✗	✗	✗	✓	✗
[34]	Capacitated Facility Location	Total annual cost minimization	✓	✓	✓	✓	✗	✓	✓
[31]	Hierarchical p-median	Distance minimization	✓	✗	✗	✗	✗	✓	✗
[32]	Capacitated p-median and maximal coverage	Distance minimization/Coverage maximization	✓	✗	✗	✗	✓	✓	✗
This approach	Capacitated maximal coverage	Coverage maximization	✓	✓	✓	✓	✓	✓	✓

f1: capacity of schools, f2: current existing schools, f3: resizing of schools, f4: schools with different capacities, f5: population coverage, f6: distances between students and schools, f7: budget to build/resize

Framework

- Analysis of the current state of school locations
- Analysis of the expansions of current schools
- Analysis of the locations of new schools
- Comparative between the current locations of schools and the optimal locations if we start from an empty map
- Projections and location analysis for the future.

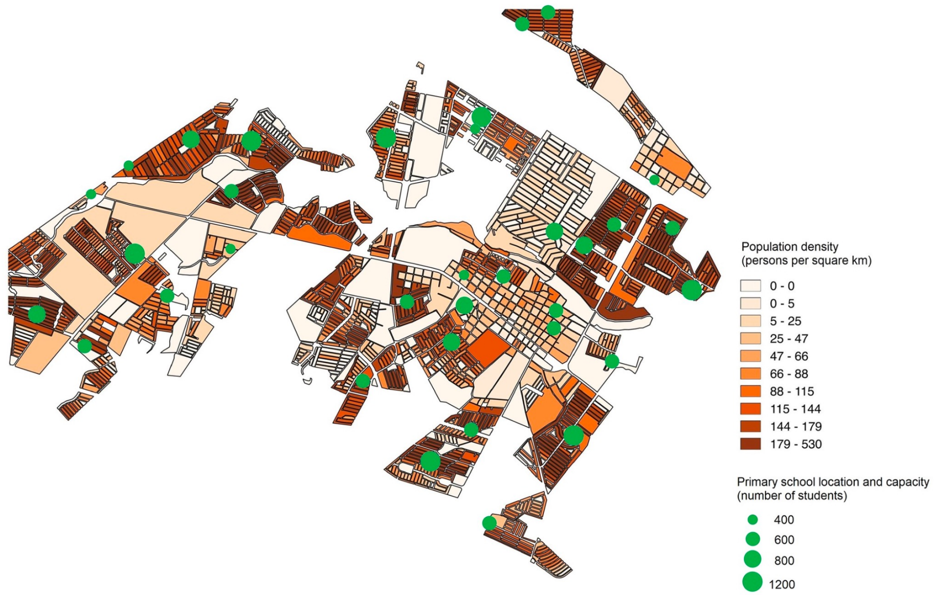


Fig 1. Population density and location of the 34 primary schools in Ciudad Benito Juárez in 2010.

Solution Proposal

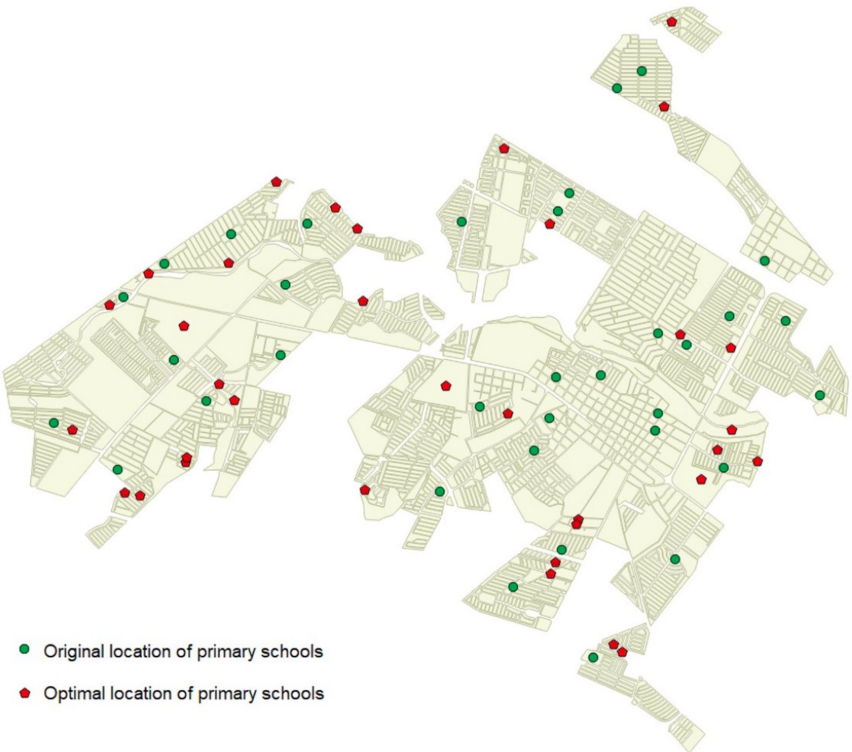


Fig 8. Comparison of original locations of schools and optimal locations of schools.

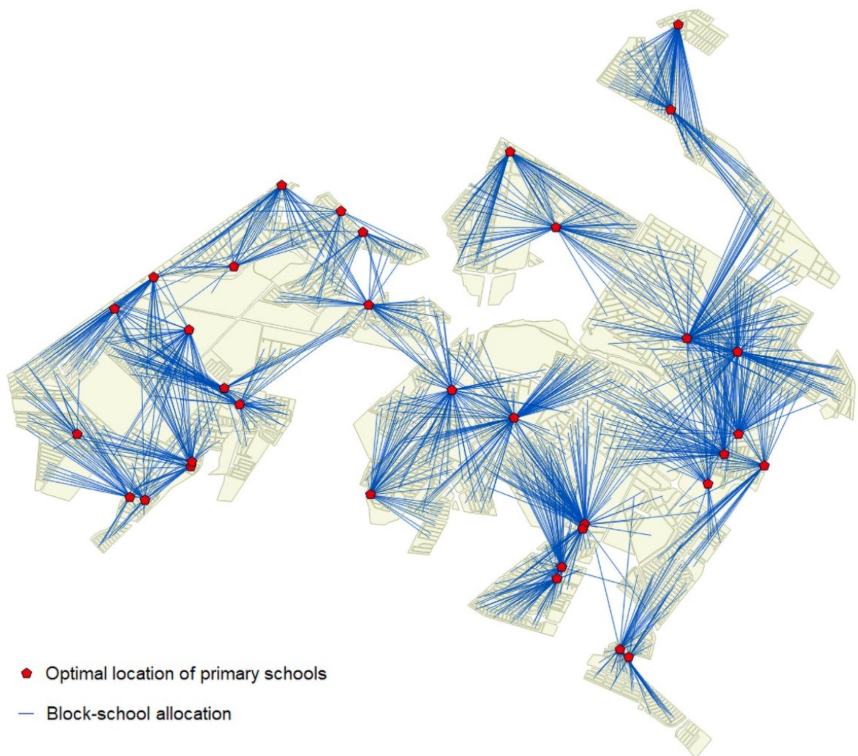


Fig 9. Block-school allocation.

3. Social Care Services

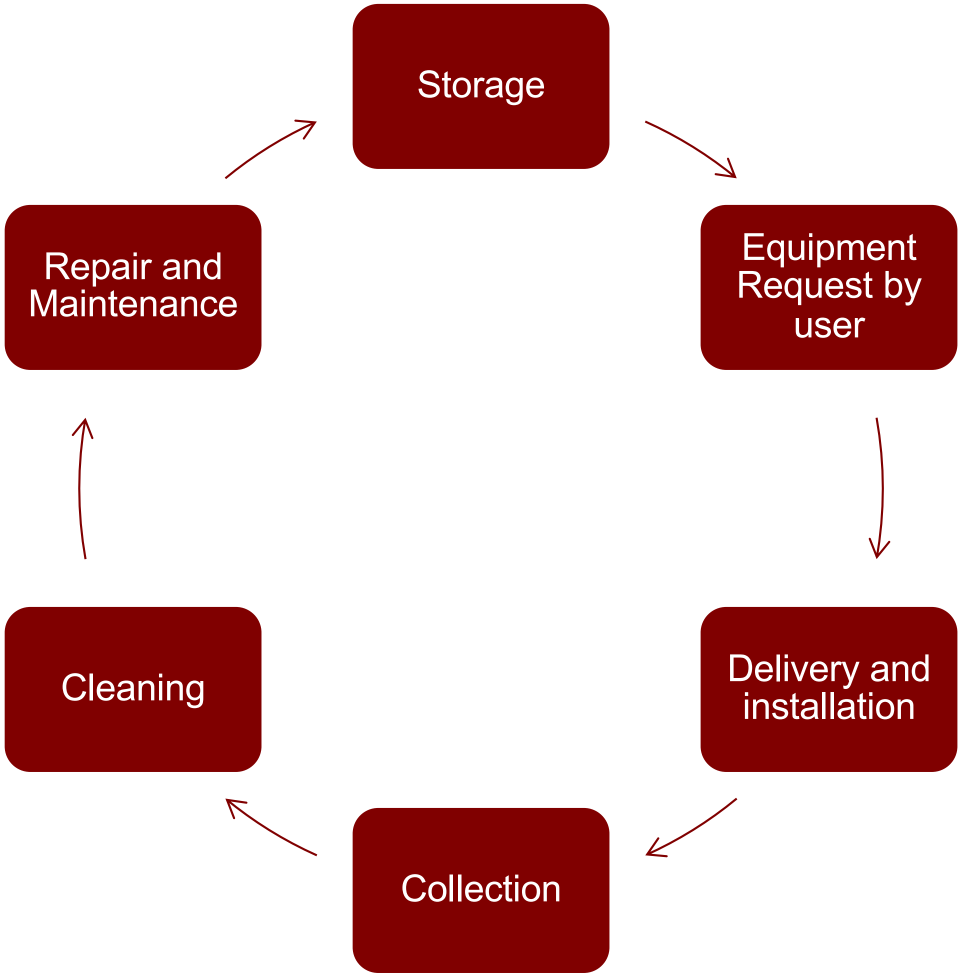
- Optimization in Assistive Technology programs: case study "Banc del Moviment" in Barcelona
  - De Armas J., Rodriguez-Pereira J. Vieira B. and Ramalhinho H. (2021), Optimizing Assistive Technology Operations for Ageing Populations, Sustainability, 13(12), 6925; https://doi.org/10.3390/su13126925.

World Health Organization

Assistive Technology Organization
Banc del Moviment (BM)

banc del
moviment
xarxa solidària
de productes
de suport

BM bases its service in Circular Economy principles



Optimizing the AT Operations

- Three main operational problems in the Assistive Technology (AT) programs:
  - the location of warehouses and customer service points
  - the inventory management of the different types of equipment
  - the optimization of the pick-up and delivery routes.

Location of warehouses and customer service points

	A	B	C	D	E	F
1	ID	Nom	X	Y	Demand service 1	Demand service 2
2	1	el Raval	2.1704919	41.378963	1	2
3	2	el Barri Gòtic	2.1774467	41.381099	2	6
4	3	la Barceloneta	2.1901586	41.377202	3	5
5	4	Sant Pere Santa Caterina i la Ribera	2.1834368	41.386794	7	5
6	5	el Fort Pienc	2.1814867	41.397418	4	6
7	6	la Sagrada Família	2.1765842	41.405448	3	4
8	7	la Dreta de l'Eixample	2.1681985	41.393885	9	4
9	8	l 'Antiga Esquerra de l'Eixample	2.1551509	41.389357	5	9
10	9	la Nova Esquerra de l'Eixample	2.1489777	41.38306	7	10
11	10	Sant Antoni	2.1593504	41.378538	2	7
12	11	el Poble Sec	2.1582486	41.365416	7	3
13	12	la Marina del Prat Vermell	2.142603	41.339334	2	5
14	13	la Marina de Port	2.1398416	41.35997	2	1
15	14	la Font de la Guatlla	2.1448466	41.369748	10	6
16	15	Hostafrancs	2.1442432	41.375317	9	6
17	16	la Bordeta	2.1364107	41.36904	4	4
18	17	Sants - Badal	2.1277307	41.374675	6	0
19	18	Sants	2.136348	41.377466	9	5
20	19	les Corts	2.1346997	41.386939	8	10
21	20	la Maternitat i Sant Ramon	2.1174165	41.381218	4	3

... 0.Start | 1.Locations | 2.Demand

$$\text{Minimize} \sum_{k\in K}\sum_{i\in I}\sum_{j\in J} d_j c_{kij} x_{kij} + \sum_{k\in K\cup I} f_k y_k, \quad (7)$$

subject to

$$\sum_{k\in K}\sum_{i\in I} x_{kij} = 1 \qquad \forall j \in J, \quad (8)$$

$$x_{kij} \le y_k \qquad \forall k \in K,\ i \in I,\ j \in J, \quad (9)$$

$$x_{kij} \le y_i \qquad \forall k \in K,\ i \in I,\ j \in J, \quad (10)$$

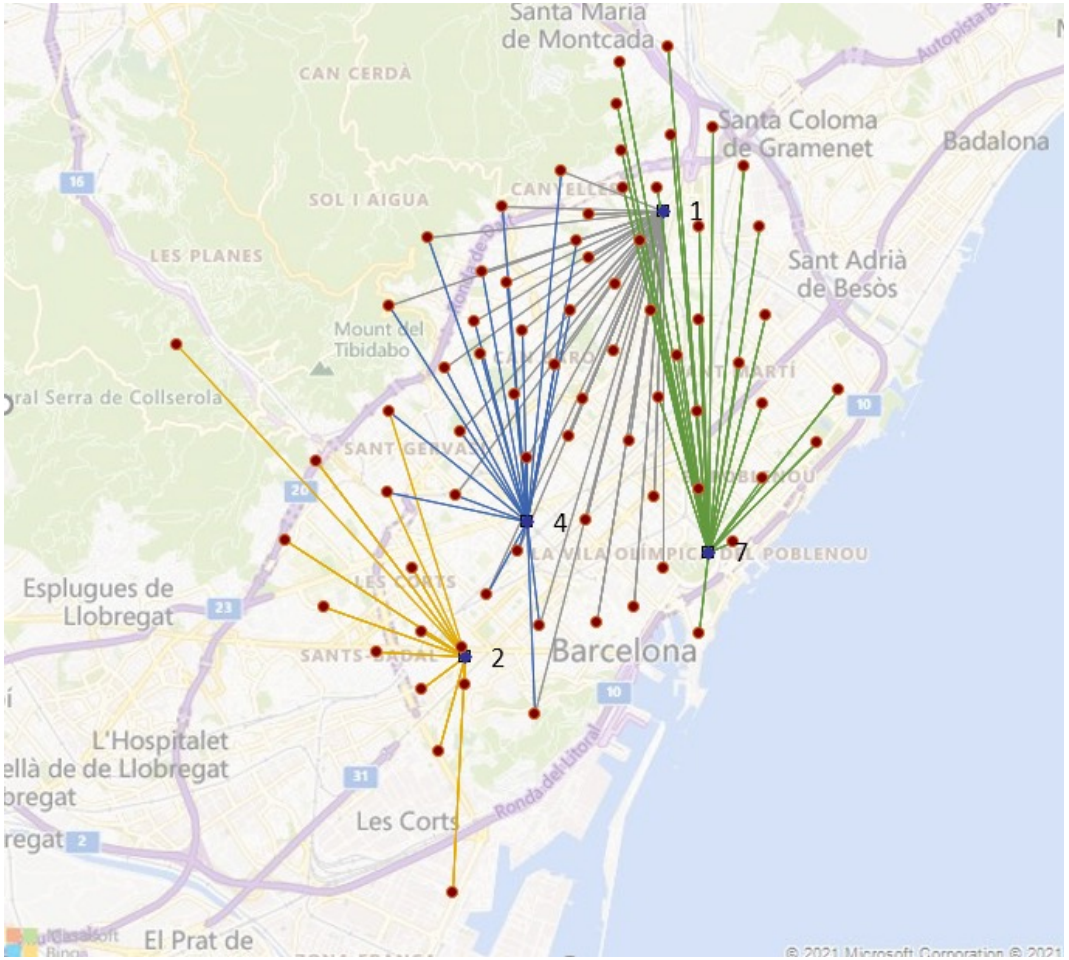
$$\sum_{k\in K} y_k = p_1, \quad (11)$$

$$\sum_{i\in I} y_i = p_2, \quad (12)$$

$$y_k \in \{0,1\} \qquad \forall k \in K \cup I, \quad (13)$$

$$x_{kij} \in \{0,1\} \qquad \forall k \in K,\ i \in I,\ j \in J. \quad (14)$$

Location of warehouses and customer service points



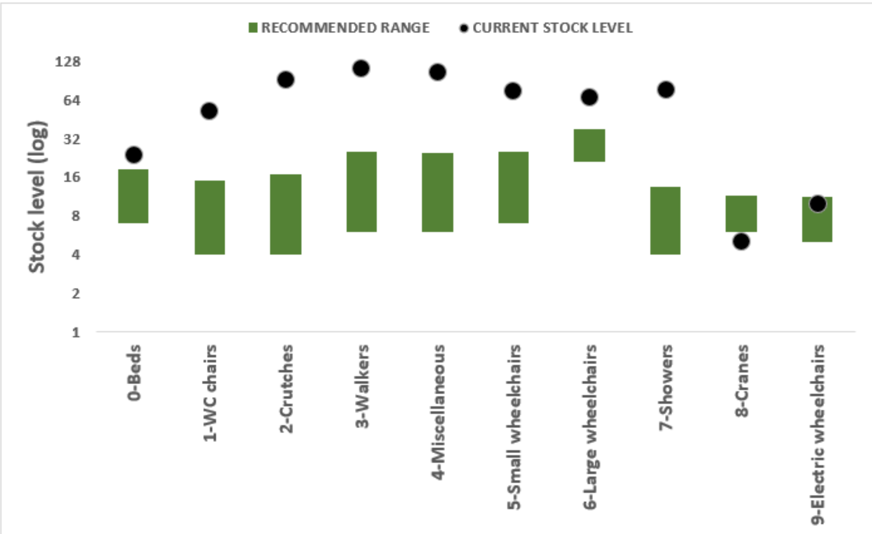
- Visualization example for a p-median problem.

Inventory management of the different types of equipment

INVENTORY MANAGEMENT - BANC DEL MOVIMENT

PRODUCTS AVAILABLE	DATE	SERVICE LEVEL (%)
623	09/04/2021	99.00%

STATUS	FAMILY	PRODUCT	CURRENT STOCK LEVEL	LEAD TIME (DAYS)	TIME BETWEEN REVIEWS (DAYS)	REORDER POINT (ROP)	MAX STOCK LEVEL (PR)	RELATIVE IMPORTANCE (NORMALIZED)	ABC CLASSIFICATION
OK	0	0-Beds	24	14	60	7	18	0.36	B
OK	1	1-WC chairs	52	7	90	4	15	0.02	C
OK	2	2-Crutches	92	7	90	4	17	0.00	C
OK	3	3-Walkers	113	7	90	6	25	0.05	C
OK	4	4-Miscellaneous	106	7	90	6	25	0.05	C
OK	5	5-Small wheelchairs	76	7	60	7	25	0.20	B
OK	6	6-Large wheelchairs	68	14	30	21	38	0.80	A
OK	7	7-Showers	77	7	60	4	14	0.10	B
REPLACE	8	8-Cranes	5	14	30	6	12	1.00	A
OK	9	9-Electric wheelchairs	10	14	60	5	11	0.17	B



- Minimum Recommended Stock Level
- Maximum Recommended Stock Level
- ABC classification

Optimization of the pick-up and delivery routes

PARAMETER	VALUE
Number of vehicles per day	1
Number of working days per week	5
Pick-up and delivery routes	
Number of warehouses	2
Average vehicle speed	70
Bing Maps Key	

Transportation Console | 1. Pick-up locations | 2. Del

VEHICLE ID	FIXED COST PER TRIP	COST PER UNIT DISTANCE	DRIVING TIME LIMIT (min)
1	26	1,84	270
2	26	1,84	270
3	26	1,84	270
4	26	1,84	270
5	26	1,84	270

Transportation Console | 4. Vehicles

$$\text{Minimize } c \sum_{(i,j)\in E} d_{ij} \sum_{k\in K} x_{ij}^k + p \sum_{i\in C} \Big(1 - \sum_{k\in K} z_i^k\Big), \qquad (19)$$

subject to

$$\sum_{k\in K} z_i^k \le 1 \qquad \forall i \in C, \qquad (20)$$

$$\sum_{j\in\delta(i)} x_{ij}^k = z_i^k \qquad \forall i \in V,\ k \in K, \qquad (21)$$

$$\sum_{j\in\varphi(i)} x_{ji}^k = z_i^k \qquad \forall i \in V,\ k \in K, \qquad (22)$$

$$\sum_{i\in D} z_i^k = 1 \qquad \forall k \in K, \qquad (23)$$

$$\sum_{i\in C}\sum_{r\in D} w_{ir} z_i^k \le Q \qquad \forall k \in K, \qquad (24)$$

$$\sum_{k\in K} x_{ir}^k \le b_{ir} \qquad \forall i \in C, r \in D, \qquad (25)$$

$$\sum_{k\in K} x_{ri}^k \le b_{ir} \qquad \forall i \in C, r \in D, \qquad (26)$$

$$\sum_{k\in K} x_{ij}^k + b_{ir} + \sum_{m\in D, m\neq r} b_{jm} \le 2 \qquad \forall i,j \in C, i \neq j, r \in D, \qquad (27)$$

$$\sum_{(i,j)\in E} t_{ij} x_{ij}^k \le 270 \qquad \forall k \in K, \qquad (28)$$

$$u_i^k - u_j^k + Q x_{ij}^k \le Q - \sum_{r\in D} w_{jr} \qquad \forall i,j \in C\{i \neq j\},$$

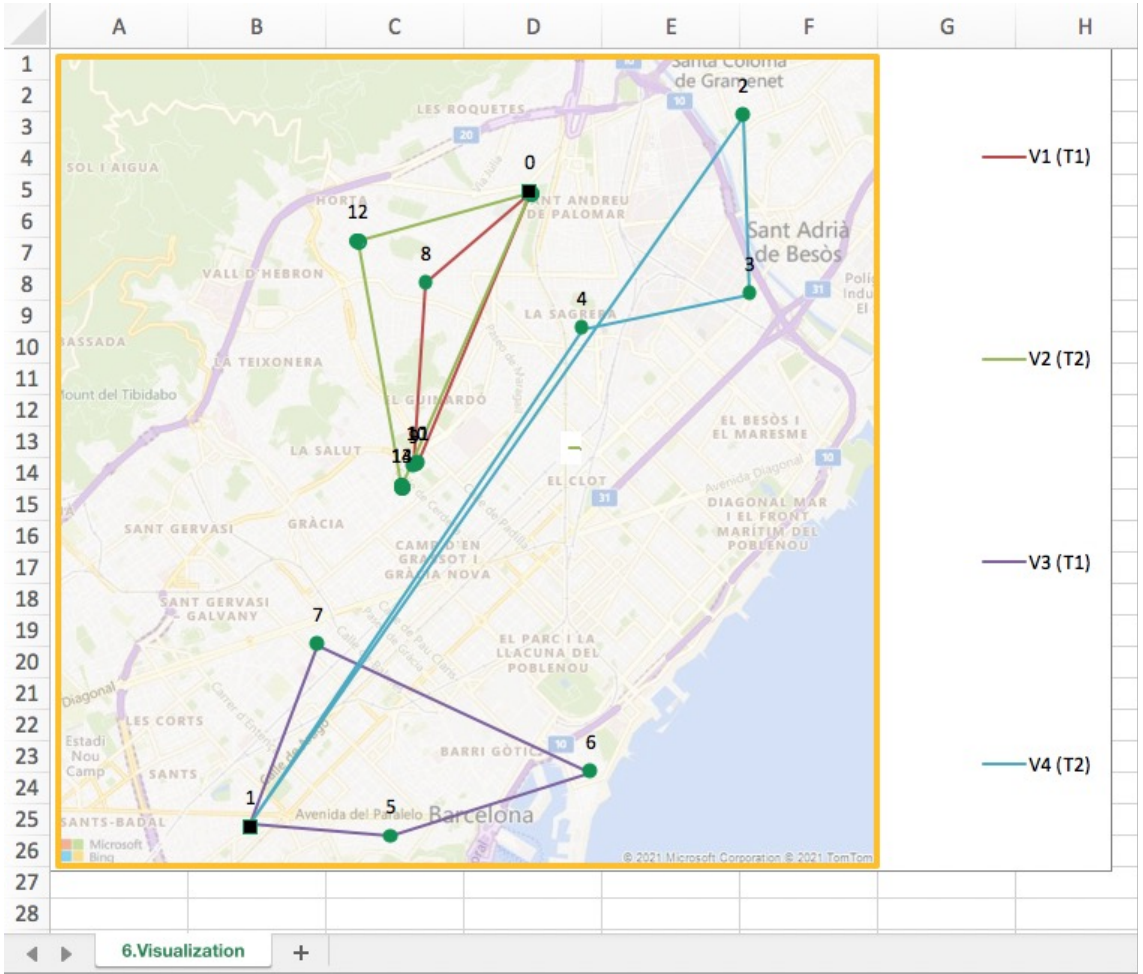
$$w_{ir} + w_{jr} \le Q,\ k \in K, \qquad (29)$$

$$z_i^k \sum_{r\in D} w_{ir} \le u_i^k \le Q z_i^k \qquad \forall i \in C, k \in K, \qquad (30)$$

$$u_i^k \in Z^+ \qquad \forall i \in C, k \in K, \qquad (31)$$

$$z_i^k \in \{0,1\}, x_{ij}^k \in \{0,1\} \qquad \forall (i,j) \in E, k \in K. \qquad (32)$$

Optimization of the pick-up and delivery routes



- Visual representation of the routes in a map using Bing Maps.

4. Heuristic Algorithm Tool for Planning Mass Vaccine Campaigns

- Rodriguez-Pereira J., Sarrá P. and Ramalhinho H. (2025) Heuristic Algorithm Tool for Planning Mass Vaccine Campaigns, Journal of Humanitarian Logistics and Supply Chain Management, 15:2, 123-134 DOI 10.1108/JHLSCM-09-2023-0082
  - https://www.emerald.com/jhlscm/article/15/2/123/1247185/Heuristic-algorithm-tool-for-planning-mass-vaccine

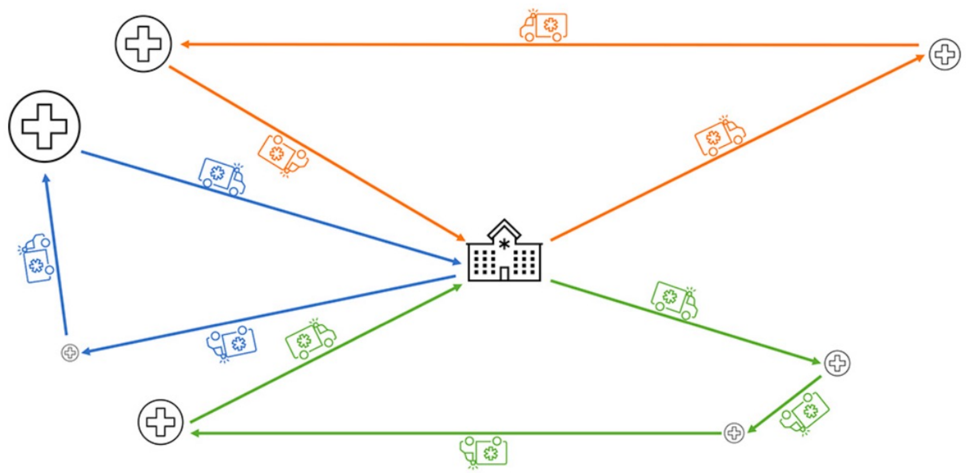
Planning Mass Vaccine Campaigns

- Vaccination campaigns are one-off activities that are carried out as a preventive measure when the risk of an outbreak is high (for example, displaced population) or as a response when an outbreak has already been detected.
- The goal of vaccination campaigns is to immunize a large number of people in a short period of time.
- The goal is not only to determine the location and allocation of vaccination centers but also to determine the assignment of medical teams to vaccination centers while defining their time schedule and route.

Algorithm - Planning Mass Vaccine Campaigns

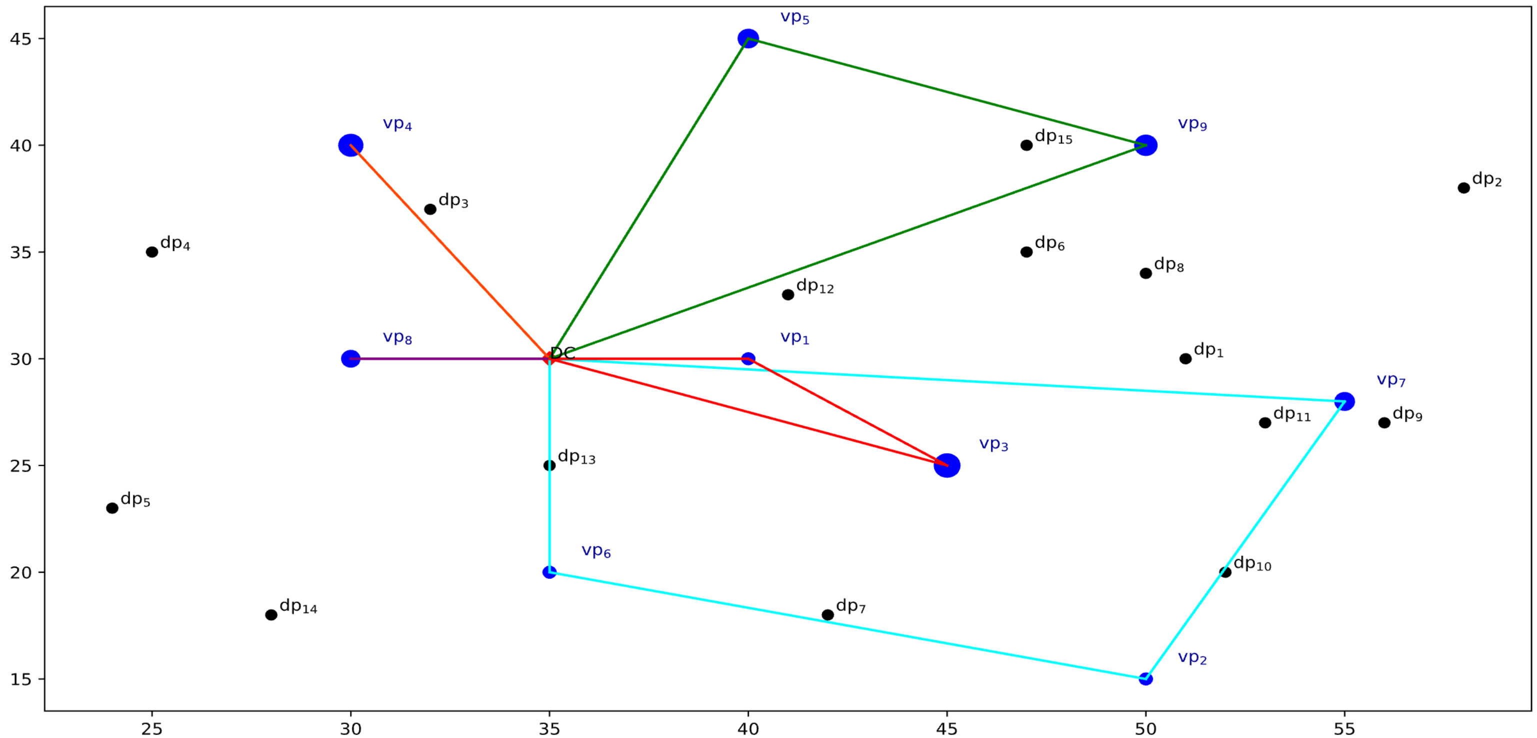
- The location-allocation phase
  - a constructive heuristic is applied to select the vaccination centers and assign the population areas to them.
- The route-schedule phase
  - for each medical team, the route and, indirectly, the schedule are obtained by applying a modification of the Clarke and Wright's savings algorithm.

Figure 3 Solution of the modified Clarke and Wright's savings algorithm with balance in the workload per route



Excel Tool - Planning Mass Vaccine Campaigns

- Planning Mass Vaccination Campaign Problem
  - jointly tackles location, allocation, scheduling, and routing decisions.
  - A mixed integer linear model and proposed an heuristic approach which has been integrated in an Excel spreadsheet



5. Mobility Optimization for Social Care Services

- Portell L. and Ramalhinho H. (2025) The Rich Heterogeneous Dial-a-Ride Problem with Trip Time Prediction, International Transactions in Operational Research, 32:2 692–718 https://doi.org/10.1111/itor.13415
- Portell, L., Rodríguez-Pereira, J., Ramalhinho, H. (2025). Optimization of Shared Trips in the Door-to-Door Transportation Service for People with Disabilities: A Case Study in Barcelona. In: Juan, A.A., Faulin, J., Lopez-Lopez, D. (eds) Decision Sciences. DSA ISC 2024. Lecture Notes in Computer Science, vol 14779. Springer, Cham. https://doi.org/10.1007/978-3-031-78241-1_23
- Portell L., Morera S., Ramalhinho H. (2022), Door-to-door Transportation Services for Reduced Mobility Population: A Descriptive Analytics of the city of Barcelona. International Journal of Environmental Research and Public Health. 19(8), 4536. https://doi.org/10.3390/ijerph19084536

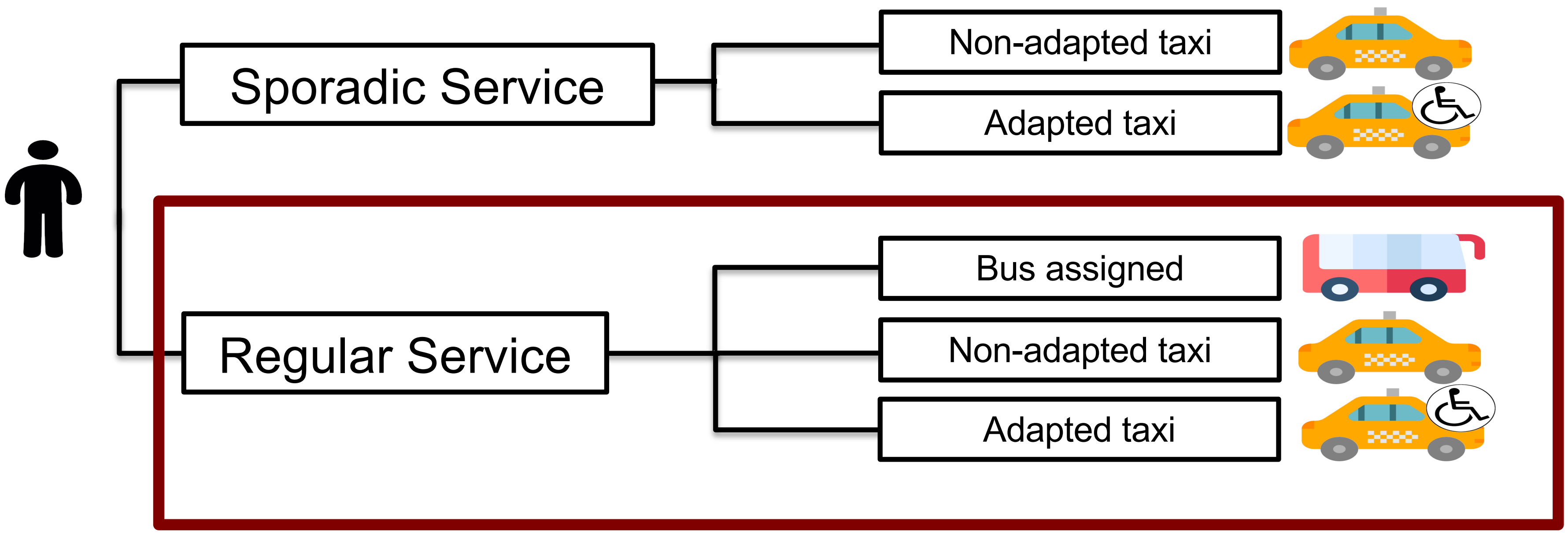
Mobility optimization for social care services

- Scheduling sustainable Transportation for persons with reduced mobility
- Mobility improves que quality of life of People with Reduced Mobility

Figure. Adapted taxi providing special transport service. Adapted from "Ajuntament de Barcelona" retrieved from https://ajuntament.barcelona.cat

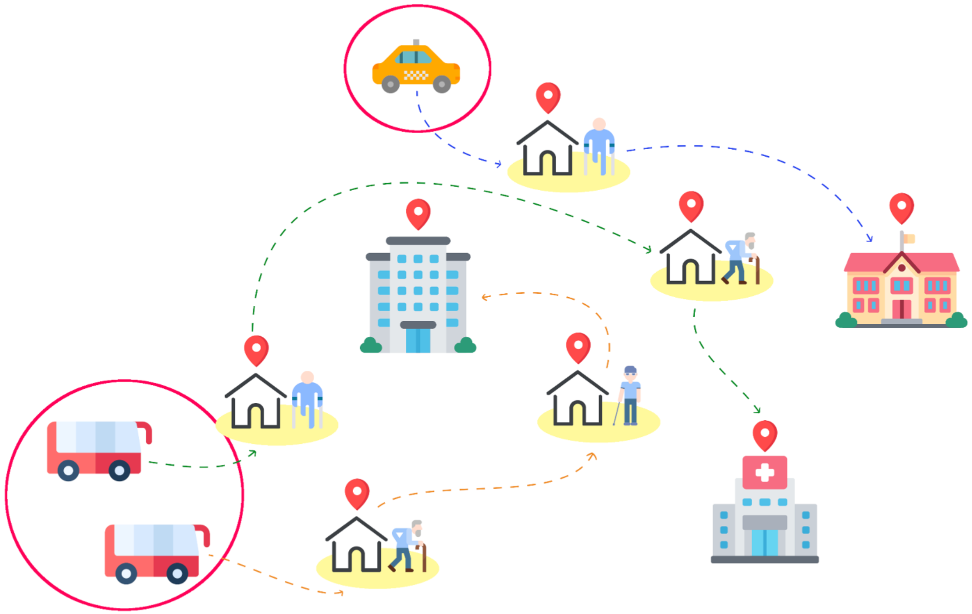
Mobility optimization for social care services

- Barcelona City Council
  - Special Municipal Transport Service
  - Accessible Transportation services



Problem Definition

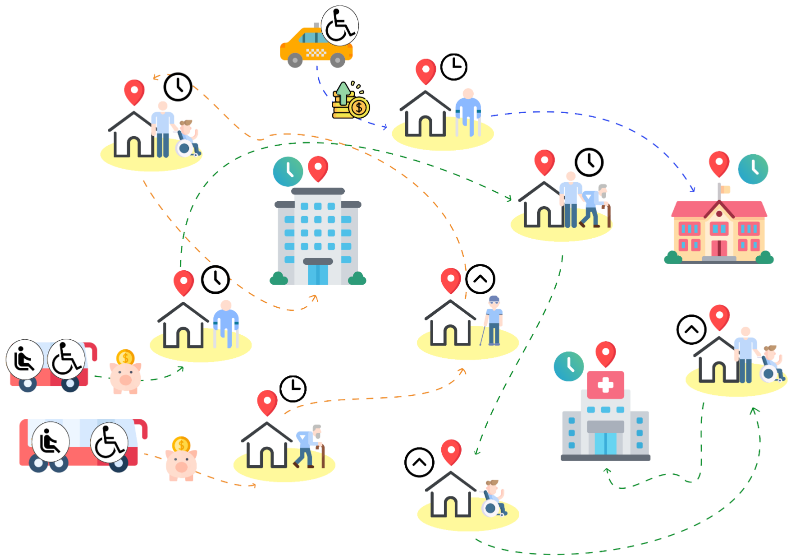
"The **Dial-a-Ride Problem** (DARP) consists of designing vehicle routes and schedules for *n* users who specify pickup and delivery requests between origins and destinations."



Cordeau, JF., Laporte, G. The dial-a-ride problem: models and algorithms. Ann Oper Res 153, 29–46 (2007). https://doi.org/10.1007/s10479-007-0170-8

Constraints

- Pickup time windows satisfied
- Maximum waiting time for a vehicle with users
- Maximum ride time per vehicle not exceeded
- Maximum ride time per user not exceeded
- Maximum vehicle capacity not exceeded
- Accompanying person in vehicle if needed



Objective Function

$$\min \sum_{k\in K} c^k \sum_{(i,j)\in A} d_{ij} x_{ij}^k + \sum_{k\in K} f^k \sum_{i\in P} y_i^k + C \sum_{k\in K} v^k$$

COST PER DISTANCE TRAVELLED

COST PER VEHICLE TRIP

COST OF ACCOMPANYING PERSON

Mathematical Model

$$min \sum_{k\in K} \sum_{(i,j)\in A} c_k \Delta_{ij} x_{ij}^k + \sum_{k\in K} \sum_{i\in P} f_k y_i^k + \sum_{k\in K} tt_k C$$

$$\sum_{j\in V} x_{ij}^k = \sum_{j\in V} x_{ji}^k = y_i^k \quad \forall i \in P \cup D, k \in K \qquad (2)$$

$$\sum_{k\in K} y_i^k = 1 \quad \forall i \in P \qquad (3)$$

$$y_i^k = y_{i+n}^k \quad \forall i \in P, k \in K \qquad (4)$$

$$\sum_{i\in P} x_{o_k^+ i}^k - \sum_{i\in D} x_{i o_k^-}^k = 0 \quad \forall k \in K \qquad (5)$$

$$w_j^k - w_i^k - t_{ij} - s_i + M(1 - x_{ij}^k) \geq 0 \quad \forall (i,j) \in A, k \in K \qquad (6)$$

$$w_j^k - w_i^k - t_{ij} - s_i - M(1 - x_{ij}^k) \leq wt \quad \forall (i,j) \in A, k \in K \qquad (7)$$

$$h_i - \delta \leq w_i^k \leq h_i + \delta \quad \forall i \in V, k \in K \qquad (8)$$

$$w_i^k + s_i + t_{i,i+n} \leq w_{i+n}^k \quad \forall i \in P, k \in K \qquad (9)$$

$$\begin{cases} l_{i,u}^k \leq Q_u^k - z^k, & \text{if } u = 0, \\ l_{i,u}^k \leq Q_u^k, & \text{if } u = 1. \end{cases} \quad \forall i \in P, k \in K \qquad (10)$$

$$l_{j,u}^k \geq l_{i,u}^k + \Phi_j^u - M(1 - x_{ij}^k) \quad \forall (i,j) \in A, u \in U, k \in K \qquad (11)$$

$$w_{i+n}^k - w_i^k - s_i \leq T \quad \forall i \in P, k \in K \qquad (12)$$

$$w_{2n+m+k}^k - w_{2n+k}^k \leq \bar{T} \quad \forall k \in K \qquad (13)$$

$$y_i^k \gamma_i \leq z_k \quad \forall i \in P, k \in K \qquad (14)$$

$$w_{2n+m+k}^k - w_{2n+k}^k - M(1 - z_k) \leq tt_k \quad \forall k \in K \qquad (15)$$

$$x_{ij}^k \in \{0,1\} \quad \forall (i,j) \in A, k \in K \qquad (16)$$

$$y_i^k \in \{0,1\} \quad \forall i \in V, k \in K \qquad (17)$$

$$z_k \in \{0,1\} \quad \forall k \in K \qquad (18)$$

$$l_{i,u}^k \in \mathbb{Z}^+ \quad i \in V, u \in U, k \in K \qquad (19)$$

$$w_i^k \in \mathbb{R}^r \quad \forall i \in V, k \in K \qquad (20)$$

$$tt^k \in \mathbb{Z}^+ \quad \forall k \in K \qquad (21)$$

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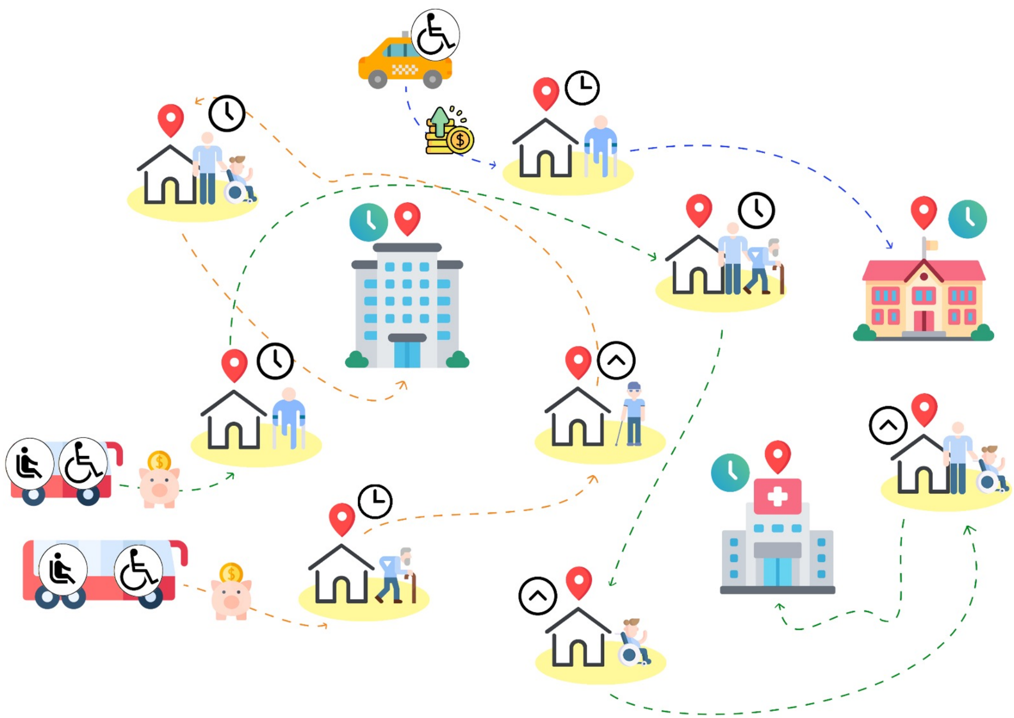
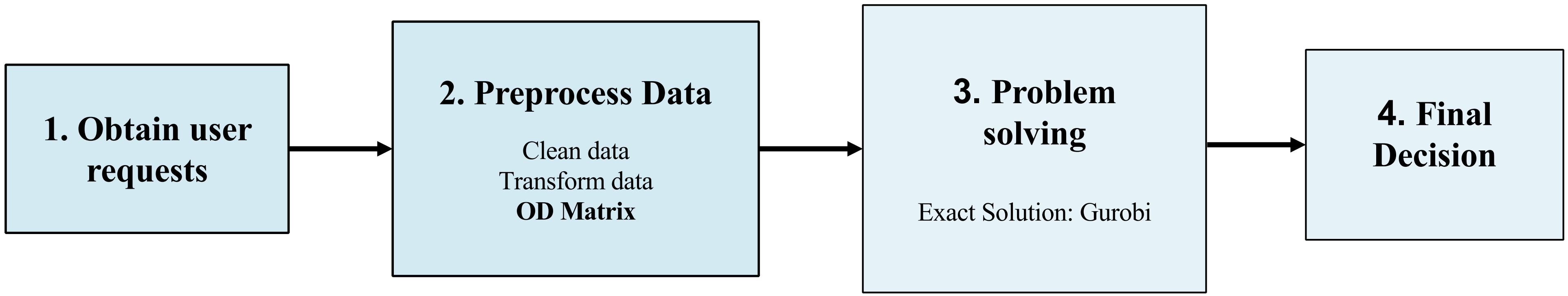
Input Data



- **Users requests**
  - Origin and destination
  - Desired pick-up time
  - Wheelchair
  - Need of companion
- **The fleet**
  - Number of buses and taxis
  - Passenger capacity for wheelchair and regular seats
  - Trip cost
  - Distance cost
  - Maximum driving time
- **Service characteristics**
  - Maximum ride time per user
  - Time-windows size
  - Maximum waiting time in a location
  - Service duration for pick-up or delivery location
  - Cost of companion per unit of time
  - Travel time between locations
  - Distance between locations

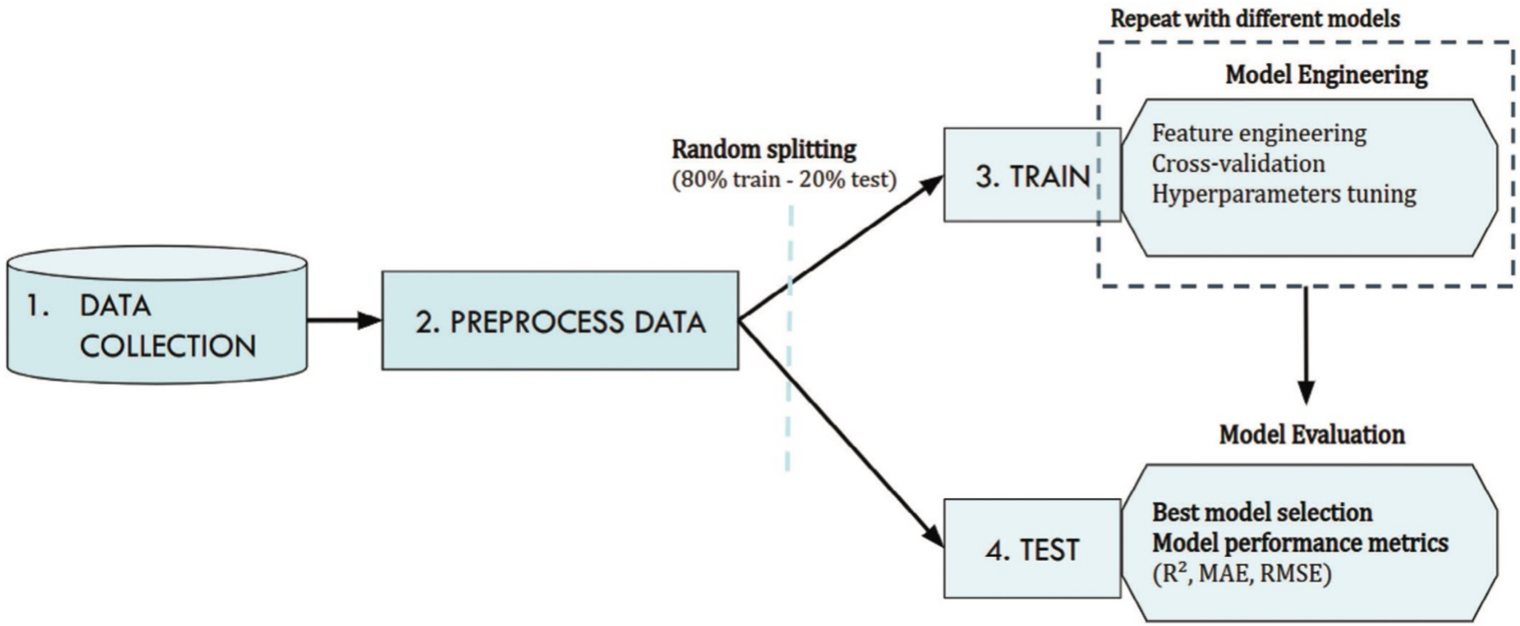
Overall SYSTEM



- Data Challenge – OD Matrix
  - Travel time varies depending on the time of day and day of the week.
  - Need to develop a predictive modeling for trip duration estimation

Predictive modeling for trip duration estimation

- Flow chart of the methodology for creating a predictive model of vehicle duration between locations, including data collection, preprocessing, training, and testing.



Case study – SMTS in Barcelona

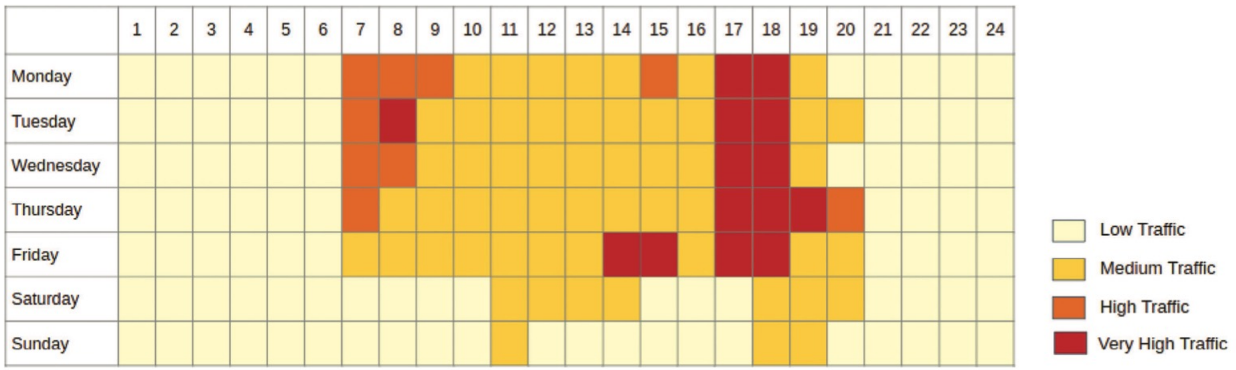
- SMTS in Barcelona
  - a door-to-door public transportation service specifically designed for people with reduced mobility.

Summary of users in different routes

Route	No. of users	No. of users with wheelchair	No. of users with companion
A	7	3	1
B	8	6	2
C	6	4	1
D	5	3	4
E	7	2	2

Capacity of buses with different numbers of seats and wheelchair spaces

Vehicle id.	No. of seats	No. of wheelchair	No. of vehicles
1	2	4	1
2	2	4	1
3	6	1	1
4	3	6	1
5	4	6	1
6	5	6	10
7	7	5	4
8	10	4	5



Case study – SMTS in Barcelona

Comparison of key metrics between the SMTS and the solutions of our model for each of the five routes (A, B, C, D, E)

Route	Model	Total distance (km)	Companion cost (€)	Maximum user time (minutes)	Total user time (minutes)	No. of buses	No. of taxis	Average user time (minutes)	Total cost (€)
A	SMTS	11.84	15.00	51.11	225.97	1.00	0.00	32.28	97.78
	Our model	9.28	15.00	50.00	230.71	1.00	0.00	32.96	79.86
B	SMTS	15.57	30.00	46.11	209.36	1.00	0.00	26.17	138.80
	Our model	18.44	15.00	30.65	133.47	1.00	1.00	16.68	108.34
C	SMTS	14.97	30.00	58.48	225.30	1.00	0.00	37.55	134.65
	Our model	16.02	15.00	56.00	180.48	1.00	1.00	30.08	97.64
D	SMTS	14.44	15.00	54.17	173.92	1.00	0.00	34.78	115.91
	Our model	10.06	15.00	47.04	115.18	1.00	0.00	23.04	85.29
E	SMTS	18.58	30.00	63.79	232.59	1.00	0.00	33.23	159.88
	Our model	16.85	15.00	50.29	155.84	2.00	1.00	22.26	104.64
Relative change average (%)		−7.16	−30.00	−14.85	−24.17	20.00	na	−24.17	−25.75

Case study – SMTS in Barcelona

- The results of our transportation model show significant improvements over the previous model in several key areas.
- Provide insights to the decision makers:
  - Evaluate the effects of varying the pickup time window parameters and the maximum time of a user in the vehicle
    - For example, reducing the maximum time from 75 to 45 minutes resulted in a minimum increase in the number of taxis needed, as well as the total distance and cost.
    - The number of buses and taxis also decreases as the time window increases, given the flexibility in vehicle routing.

6. Actual Work, Lessons Learned and Conclusions

Operations Research Models for Planetary and People Wellbeing

Logistics in health emergencies, social care services and needs in rural areas

Stakeholder Collaborative Engagement
Access context and data
Test solutions and make suggestions

- Health Emergency
- Social Care Services
- Rural Areas Services

Common aspects on the studied problems:

- Social value
- Uncertainty
- Adaptability
- Resilience
- Real assumptions

Theoretical Mathematical Models
Deterministic and Stochastic

Algorithms – Metaheuristics & Simheuristics
User Friendly and Online

Test and validation

Collaboration among researchers

- Managerial Implications
- Decision Making Tools
- Social Impact and wellbeing

Knowledge impact – Scientific publications

Models & Algorithms Development

- **Problem characteristics in social impact problems**
- These problems deal with **people**
  - Uncertainty
  - Resilience
  - Robustness
  - Adaptability
  - Multi-objective
  - Real assumptions
  - Applicability
  - ...
- Develop new models and algorithms

Models & Algorithms Development

- Optimization Models
  - Objective functions
    - Key performance indicators
    - Measure the **Societal Impact**
    - Social Return of Investment
  - Stochasticity
  - **Simple and easy to explain**
  - If the users do not understand it, they do not use it

- Algorithms – Metaheuristics and Simheuristics
  - User friendly and online

Lessons Learned

- Many possible applications of Optimization for Social Good.
- The challenge of developing a simple tool but that make a **positive impact in the society**.
- New state-of-the art **Models and Algorithms** based on Operations Research.
  - Stochastic elements, new objective functions, social value, real aspects and constraints, adaptability…
  - Excellent application of metaheuristics.
- The tools must be **simple to understand and use**.
- Work on **real applications**
  - Measure the **Societal Impact** (Social Return of Investment)

Recommendations

- Listen Listen Listen
  - Try to understand as much as possible the system that you want to optimize.
- Careful with the meaning of the words
  - Optimal solution as a different meaning.
- Define well the objective function
  - How to measure quality on health and social care services?
- People People People
  - You are working with people, so anything can happen.
- Explain Explain Explain
  - Explain your model and algorithm in an accessible way by everyone Simplicity is the best...

Conclusions

- The OR models work on optimizing resources, but in the health, social, humanitarian and environmental sectors, most of the time, the resources are **people**.
  - not things like boxes, cars, machines…
- The incorporation of aspect like **people satisfaction, stochasticity, simplicity and accessibility** is more relevant than never to be able to put on practice the models and algorithms developed.
- Operations Research and Analytics can make a Great Impact on the Society leading to Social Good, enhancing the efficiency of the system and leading to a greater equity.

Thanks

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